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PRE-DISASTER MULTI-HAZARD DAMAGE AND ECONOMIC LOSS ESTIMATION MODEL

Annual project report 2014-2015

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Bushfire and Natural hazards CRC

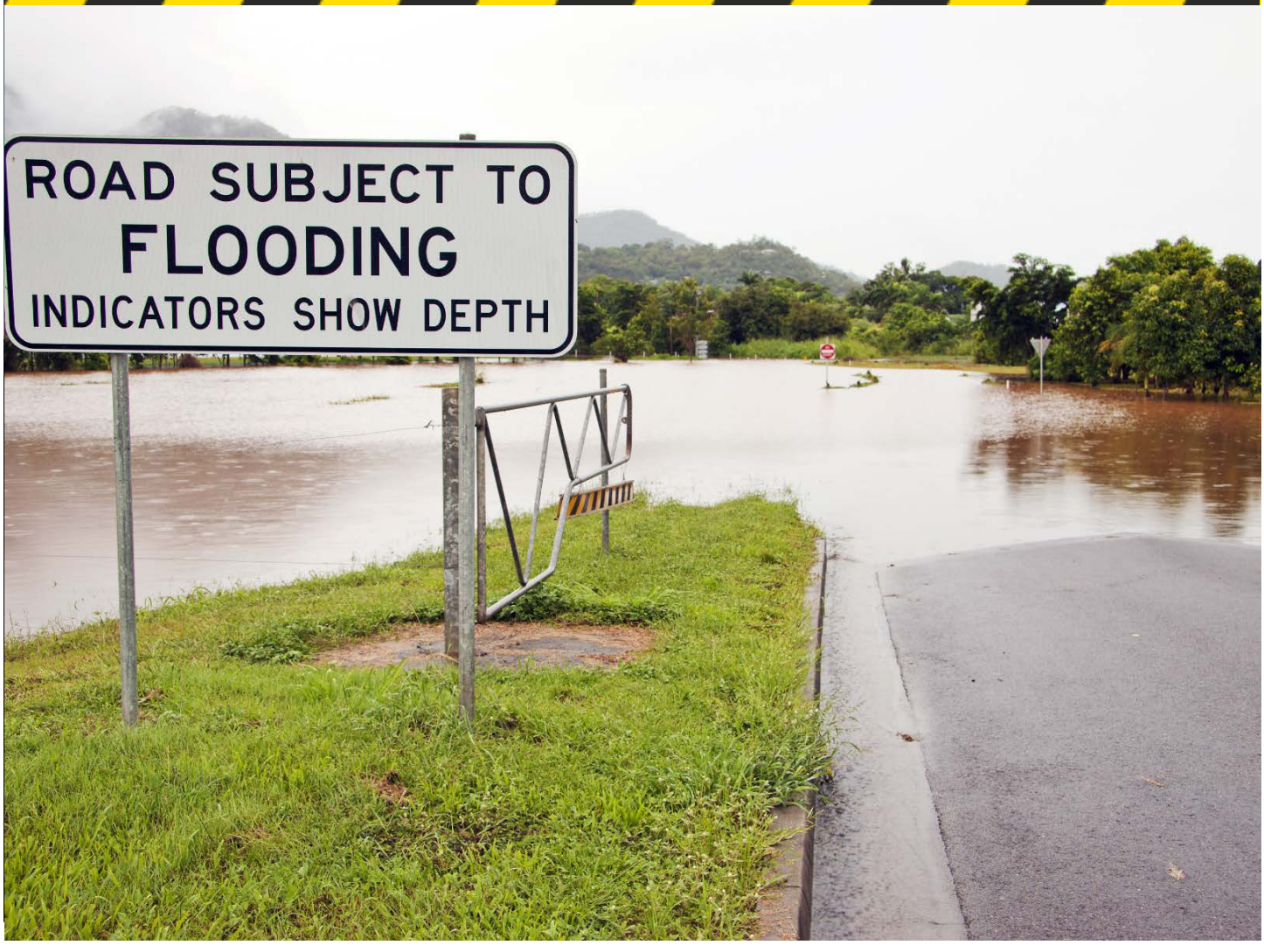

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The economic impacts are often overlooked in management planning as the effects are not immediately felt and instead focus is put onto emergency response systems. In Australia, the disaster management arrangements across all stages (mitigation, preparedness, response and recovery) have proven to be very successful at saving lives and property, however, in terms of the adverse economic impacts of the natural disasters, less attention and resources have been allocated. In Australia, natural disasters are estimated to cost an average of AU$1.14 billion annually. This makes natural disasters a significant issue for policy makers.

One of the substantial problems identified which increases this problem is the inability to estimate the full economic impact of natural hazards, considering all the affected sections of the economy. This effort should take into account not only the primary effects of the natural disasters, but also its lingering, all-important secondary effects due to the pervasive losses throughout the economy emanating from various sectors within the economy.

To address this problem this project has identified at least two major requirements that seek immediate attention to bridge the related gap. Firstly, a disaster risk assessment system needs to be developed which provides adequately quantifiable potential damages as a result of different types of disasters for regions of Australia. Secondly, a framework needs to be established to estimate the indirect economic losses. With the identification of the disaster-specific potential damage and losses, policymakers at different levels will be able to formulate disaster risk reduction-inclusive development policies to mainstream disaster resilience practices. Hence, modelling the potential impacts of a full range of natural disasters remains highly critical towards designing more informed national economic policies.

This project is primarily an economics based project applied to the scenario of natural disaster events within the context of Australia. To support the outcomes of the project and to enable a greater understanding of the outcomes the findings are displayed using a spatial visualization platform to facilitate improved decision making.

Since the commencement of the project the research team has been focused on delivering outcomes and working towards the final output. As such, to date a number of outcomes have already been achieved: development of the multi-hazard map for Victoria; development of a method to estimate the effect of natural disasters on sectoral economic growth of Australia; and numerous publications including a refereed paper accepted for Australian Conference of Economics 2015, a paper accepted for oral presentation at AFAC 2015, a report on the multi-hazard map for Victoria, a report on exposure analysis, a report on the damage and consequence data from past hazard event in Victoria, and a paper accepted and delivered for oral presentation at AFAC 2014.

END USER STATEMENT

Ed Pikusa - *South Australian Fire and Emergency Services Commission*

From the perspective of the Lead End User, following the April 2015 Research Advisory Forum, issues were raised by end users as to the processes being used. The principle of using economic analysis to assess impacts of natural disasters remains a desirable goal of end users. The issues are concerned with the specifics of data and process, and whether they will produce the desired and defensible results for end users. The CRC has initiated a review of the data and processes being considered by this project to ensure it is meeting end user needs.

INTRODUCTION

History portrays numerous natural disasters that not only reshaped topographical settings but also have bearings on the economic structures of many countries, including Australia. The economic impacts are often overlooked in management planning as they are not immediately felt and focus is put onto emergency response systems. In Australia, the disaster management arrangements across all stages (mitigation, preparedness, response and recovery) have proven to be very successful at saving lives and property. However, in terms of the adverse economic impacts of the natural disasters, less attention and resources have been allocated.

In Australia, natural disasters are estimated to cost an average of AU$1.14 billion annually[1]. This statistic, which includes the costs carried by individuals, governments, businesses etc., along with the rapid economic growth in Australia, makes natural disasters a significant issue for policy makers. One of the substantial issues identified in this connection is the inability to estimate the full economic impact of natural hazards, considering all the affected sections of the economy. This effort should take into account not only the primary effects of the natural disasters, but also its lingering, all-important secondary effects due to the pervasive losses throughout the economy emanating from various sectors within the economy. In order to achieve a paradigm shift from reactive response to a proactive risk reduction culture, disaster risk reduction measures need to be integrated into the economic development process.

In order to achieve this shift, this research program will be a pioneering effort in mainstreaming disaster risk reduction (DRR) measures into the economic development process. The overall objective of this research project is to build a scenario-based pre-disaster multi-hazard damage and economic loss estimation model to support decision makers in reducing disaster risks.

Australia is the primal beneficiary of this research on a number of levels. First, at the national level, the research will investigate the economic impact of natural disasters on the growth of sectors in the Australian economy such as agriculture, forestry and fishing, mining, manufacturing, utilities, construction, retail trade, transport, health care etc. At the state level in Victoria, in addition to the national benefits, the research will assess the multi-hazard risks for the three natural disasters of bushfires, floods, and earthquakes and will estimate the potential damages and economic losses created by these events. This will enable the identification of optimum economic policy options to recover or minimise such adverse effects.

This report provides a comprehensive overview of the project to date and includes a short background on the project, the project aims, objectives, and outcomes, and details the work that has taken place on this project to date.

PROJECT BACKGROUND

With the financial assistance and overall guidance of the Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC), the Centre for Disaster Management and Public Safety (CDMPS), University of Melbourne in collaboration with the School of Accounting, Economics and Finance (AEF) at Deakin University and the Asian Disaster Preparedness Centre (ADPC) is leading a research project titled "Pre-disaster Multi-hazard Damage and Economic Loss Estimation Model."

WHY THIS PROJECT IS IMPORTANT

History portrays numerous natural disasters that not only reshaped topographical settings but also have bearings on the economic structures of many countries, including Australia. The economic impacts are often overlooked in management planning as they are not immediately felt and focus is put onto emergency response systems. In Australia, the disaster management arrangements across all stages (mitigation, preparedness, response and recovery) have proven to be very successful at saving lives and property. However, in terms of the adverse economic impacts of the natural disasters, less attention and resources have been allocated.

In Australia, natural disasters are estimated to cost an average of AU$1.14 billion annually (BTE, 2001). This statistic, which includes the costs carried by individuals, governments, businesses etc., along with the rapid economic growth in Australia, makes natural disasters a significant issue for policy makers. One of the substantial issues identified in this connection is the inability to estimate the full economic impact of natural hazards, considering all the affected sections of the economy. This effort should take into account not only the primary effects of the natural disasters, but also its lingering, all-important secondary effects due to the pervasive losses throughout the economy emanating from various sectors within the economy.

At least two major research gaps have been identified that seeks immediate attention to bridge the related gap. First, a disaster risk assessment system needs to be developed which provides adequately quantifiable potential damages as a result of different types of disasters for regions of Australia. Second, a framework needs to be established to estimate the indirect economic losses. With the identification of the disaster-specific potential damage and losses, policymakers at different levels will be able to formulate disaster risk reduction-inclusive development policies to mainstream disaster resilience practices. Hence, modelling the potential impacts of a full range of natural disasters remains highly critical towards designing more informed national economic policies. An immediate intervention in this regard is indispensable to increase the level of disaster risk resilience of the Australian economy.

To move from reactive response to a proactive risk reduction culture, this research program will be a pioneering effort in mainstreaming disaster risk reduction (DRR) measures into the economic development process. The overall objective of the research project titled- 'A pre-disaster multi-hazard damage and economic loss estimation model for Australia' is to build a scenario-based

pre-disaster multi-hazard damage and economic loss estimation model to support decision makers in reducing disaster risks.

Australia is the primal beneficiary of this research on a number of levels. First, at the national level, the research will investigate the economic impact of natural disasters on the growth of sectors in the Australian economy such as agriculture, forestry and fishing, mining, manufacturing, utilities, construction, retail trade, transport, health care etc. At the state level in Victoria, in addition to the national benefits, the research will assess the multi-hazard risks for the three natural disasters of bushfires, floods, and earthquakes and will estimate the potential damages and economic losses created by these events. This will enable the identification of optimum economic policy options to recover or minimise such adverse effects.

OBJECTIVES OF THE PROJECT

The objective of this research is twofold:

1. National Level: To estimate the overall impact of different types of natural disasters on national economic growth of Australia.
2. State Level: To estimate the localised effects of different types of natural disasters on economic growth of different regions within the state of Victoria through developing a spatial platform.

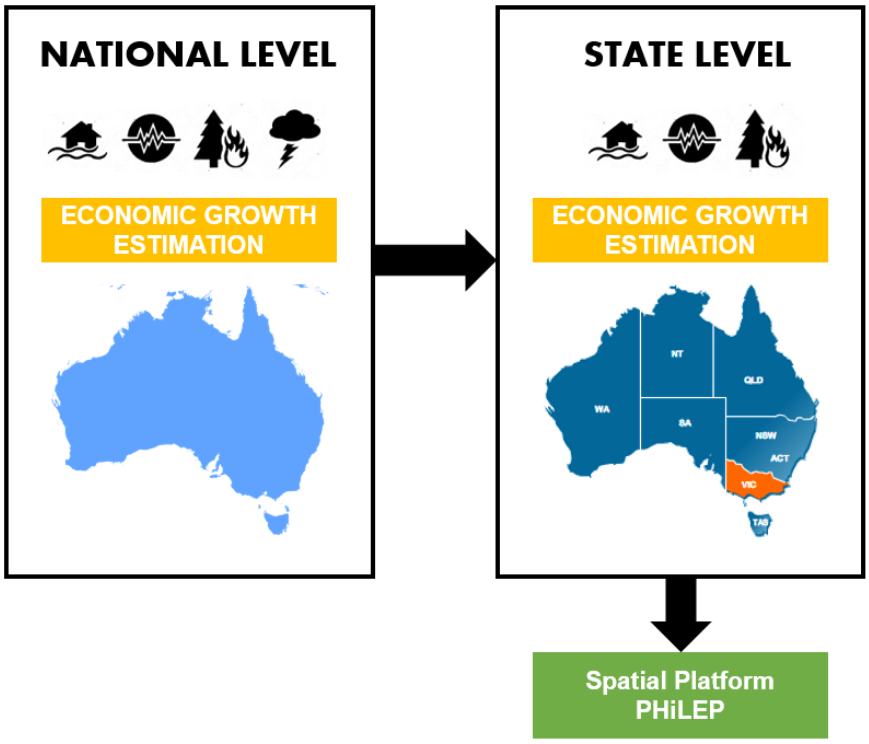


Figure 1: the objectives of the research

OUTCOMES OF THE PROJECT

Two levels of outcomes can be considered for this project: outcomes at the national level, and outcomes at the state level – which for this research focuses on the state of Victoria.

National Level

At national level, the project will develop and provide an estimation framework which can deliver assist the end users to estimate the overall economic costs of natural disasters in Australia. In particular, at the national level this initiative is the first of its kind to:

1. An estimation of the economic cost of bushfires, floods, storms and earthquakes on national economic growth of Australia by economic sectors (e.g., agriculture, manufacturing and services)
2. Identification of the economic sectors that are vulnerable to natural disasters.
3. Identification of the economic sectors that experience natural disasters positively
4. Identification of the economic sectors that are unlikely to get affected by natural disasters
5. A ranked list of the economic sectors that seek more attention for policy intervention to minimise potential negative effects of natural disasters

State Level

The effects of natural disasters sometimes cannot be observed at national level, however its localised effects are unavoidable. To our knowledge, this project is the first attempt to capture the localised effects of natural disasters on economic activities in the state of Victoria. We first categorize the overall economic costs of natural disasters into two groups: damage and losses. By damage, we mean the destruction of capital stock (e.g., any physical assets such as buildings and bridges); by losses we mean the consequences of natural disasters on the flow for the production of goods and services. Under this component, we first assess the potential damage of natural disasters and then estimate their effects on the flow of gross state product at local level (i.e., smaller spatial unit within a state). Finally, we add both damage and losses in a spatial platform to visualize the overall localised effects of natural disasters in Victoria.

At state level, the project will develop and provide a spatial platform which can deliver assist the end users to estimate the localised economic costs of natural disasters in the state of Victoria. In particular, at the state level this initiative is the first of its kind to deliver the following outcomes:

Assessing damage

1. Development of a multi-hazard risk assessment tool by using hazard, exposure and vulnerability maps for Victoria
2. Estimation of hazard-specific damage against a series of potential scenarios at the local level

Estimating Losses

3. Estimation of the effects of bushfires, floods and earthquakes on local economic growth of Victoria by economic sectors (e.g., agriculture, manufacturing and services)
4. Identification of the economic sectors at the local level that are vulnerable to natural disasters
5. Identification of the economic sectors at the local level that experience natural disasters positively
6. Identification of the economic sectors at the local level that are unlikely to get affected by natural disasters
7. A ranked list of the economic sectors at the local level that seek more attention for policy intervention to minimise potential negative effects of natural disasters

Natural disasters affect almost every sphere of human life. Estimating—and even defining—the economic cost of natural disasters is far from straightforward. This makes the decision-makers job more challenging. Having this in mind, all of the outcomes of this project will be spatially-enabled in that the decision-makers can visualize the potential physical damage and economic losses in a map. This innovative feature can support designing disaster risk reduction activities such that the localised effects of natural disasters would be minimised.

WHAT THE PROJECT HAS BEEN UP TO

Since the commencement of this project, the research team has been focused on delivering outcomes and working towards the final output. As such, to date a number of outcomes have already been achieved, including the development of the multi-hazard map for Victoria, the development of a method to estimate the effect of natural disasters on sectoral economic growth of Australia, a study on exposure analysis, an assessment of damage and consequence data from past hazard events in Victoria, as well as a range of engagement activities. Each outcome will be elaborated on below.

DEVELOPMENT OF THE MULTI-HAZARD MAP FOR VICTORIA

The multi-hazard map for Victoria is a key input for the multi-hazard disaster risk assessment component of the overall project. The multi-hazard map was developed in the primary stages of the project to support these additional components later on in the project. The map compiles available hazard maps from a range of sources that focus on the natural hazards of bushfires, floods and earthquakes. The multi-hazard is supported by the PHiLEP system which is introduced briefly below, following this, a snapshot of the development of the multi-hazard map is given, as well as the outputs of the map. A comprehensive report on the development of the multi-hazard map has been developed and is available. Details of this report are shown below in the publications section.

PHiLEP system

The PHiLEP system (pre-disaster hazard loss estimation platform) has been created as a platform to visualize the results of this project. The initial achievement of a multi-hazard map for Victoria has been created and is available for use through the PHiLEP system. Within this project, the PHiLEP platform is used as a foundation to facilitate the development and visualisation of a pre-disaster multi-hazard damage and economic loss estimation model.

The PHiLEP platform aims to enhance decision making through the provision of better information for decision makers. In particular, the PHiLEP platform can facilitate the decision making process for natural catastrophes such as flood and bushfire by utilising a combination of disaster modelling, spatial data analysis, visualisation and optimisation technologies.

The PHiLEP performs real-time collection, management, analysis, distribution, and visualisation of information for enhanced situational-awareness. This enables a real-time stream of critical information to enter the system and populate the optimisation/simulation engine to develop time-based scenarios to increase the cognitive abilities of decision-makers when faced with disaster events of large magnitude and uncertainty.

The PHiLEP system has a sophisticated design and the complexity of the PHiLEP system comes from its mixed nature: on one hand, it is a data-driven system, which needs to access and manage homogenous geospatial data from distributed sources as well as the validated Volunteered Geographic Information (VGI) from crowd-sourced platforms; on the other hand, it can also be treated as a model-driven system since all the modules and functionalities are designed

to integrate and extend various existing disaster models. Hence, the system design goals should include:

- Providing mechanisms for geospatial data management conforming OGC standards
- Enabling crowd-sourced VGI information
- Being easy to plug-in with external disaster models
- Providing universal analysis methods for disaster decision making
- Aggregating open-sourced frameworks for geospatial analysis, modelling and visualization

The conceptual model of the PHiLEP platform is shown below in Figure 2. The PHiLEP is at the centre of the model integrating a smart geospatial information platform with an advanced optimization and simulation engine. The smart geospatial platform harness information from a range of sources including the bureau of meteorology, local governments, emergency services, social media etc. – in real time and can perform analysis and visualization of the data. Decision makers can access the information, data and optimization elements through the IDDSS and they can perform their own analyses, simulations and scenarios to support the management of disaster events.

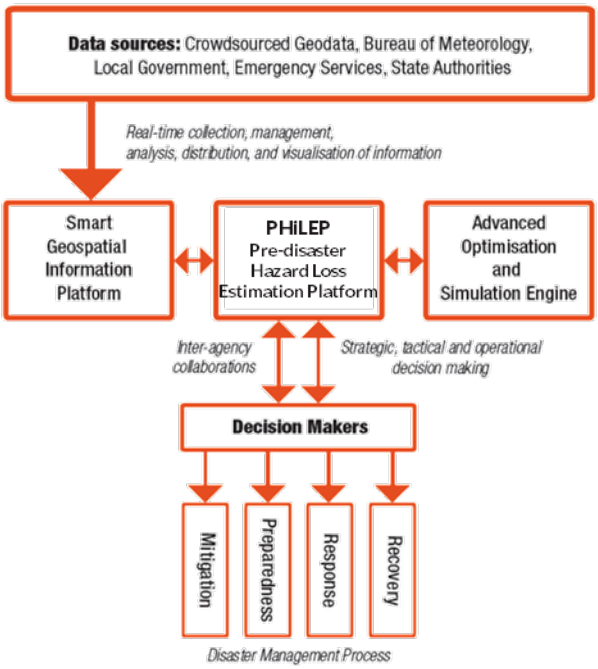


Figure 2: The conceptual model of the PHiLEP system

Development of the Multi-hazard Disaster Risk Map

In order to develop a multi-hazard map for Victoria, a range of datasets were first collected, and were then integrated to build the multi-hazard map. The PHiLEP system facilitated the integration of these datasets. The datasets collected were:

- Built-in-Database in PHiLEP platform

- Destination zones (DZN) with Journey-to-Work (JTW) data for 2011, obtained from the Australian Bureau of Statistics via TableBuilder Pro
- Road network data for Victoria including freeway, highway and arterial road data, obtained from Vicmap – 2013 dataset
- Population data from the Australian Bureau of Statistics
- Employment data from Australian Bureau of Statistics
- Parcel data from Vicmap
- Bushfire hazard data extracted from the Victorian Fire Risk Register - Bushfire (VFRR-B) data set (March, 2014).
- Earthquake hazard data, obtained from Geoscience Australia 2012.
- Flood hazard data, obtained from Department of Environment and Primary Industries Victoria (DEPI).

Bushfire Hazards

The bushfire data included in the multi-hazard map comes from the Victorian Fire Risk Register – Bushfire (VFRR-B) data set which identifies assets that are potentially at risk from a bushfire – determined through the VFRR process of assessment. The model behind the data used information such as vegetation type, fuel loads, slope, separation distance, vulnerability criteria, fire history, fire spread and reach – to determine threat, consequence and likelihood ratings in order to model a final risk and priority rating.

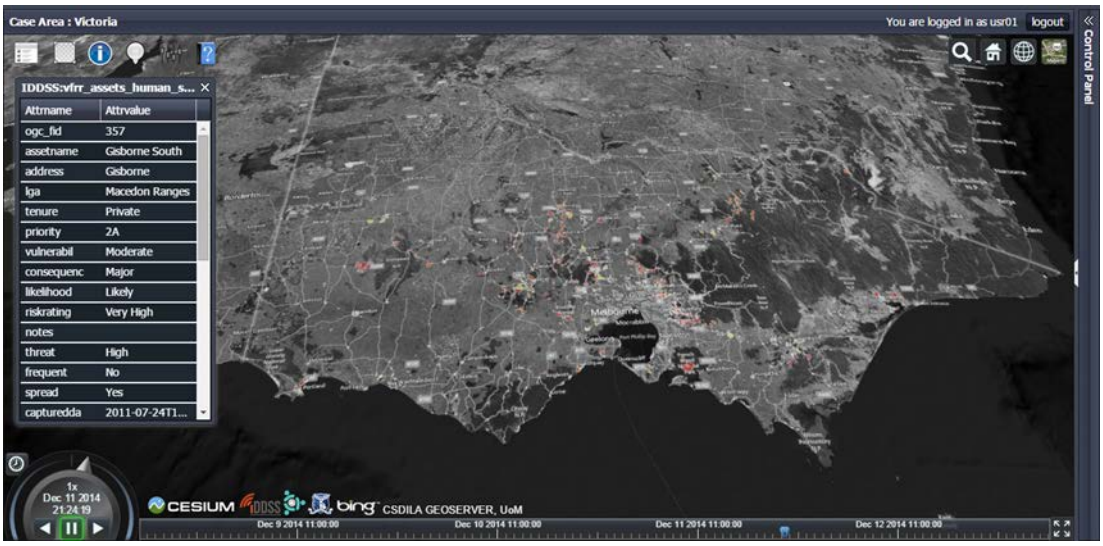


Figure 3: Bushfire hazard map

In the figure above (figure 3) the bushfire layer of the multi-hazard map is shown. This layer can be queried or used for spatial analysis.

Flood Hazards

The flood data used in the multi-hazard map was compiled by the Department of Environment and Primary Industries Victoria (DEPI) and is shown below in figure 4. The data displays a visualization of a 100 year flood extent based on the Victorian flood database.

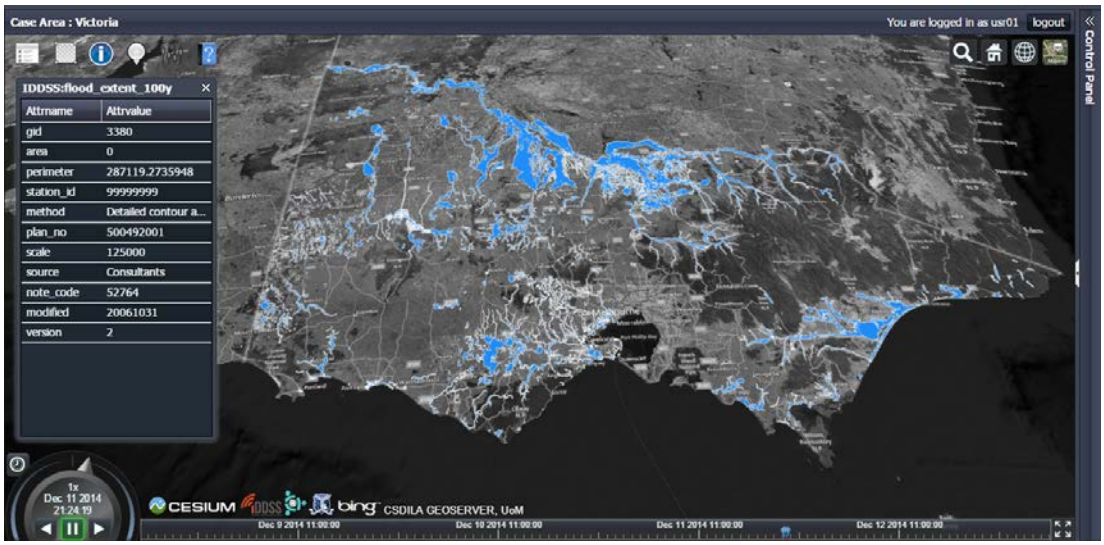


Figure 4: Flood hazard map

Earthquake Hazards

The earthquake data used in the multi-hazard map was obtained from Geoscience Australia and is shown below in Figure 5. The data displays a visualization of a 500 year peak ground acceleration.

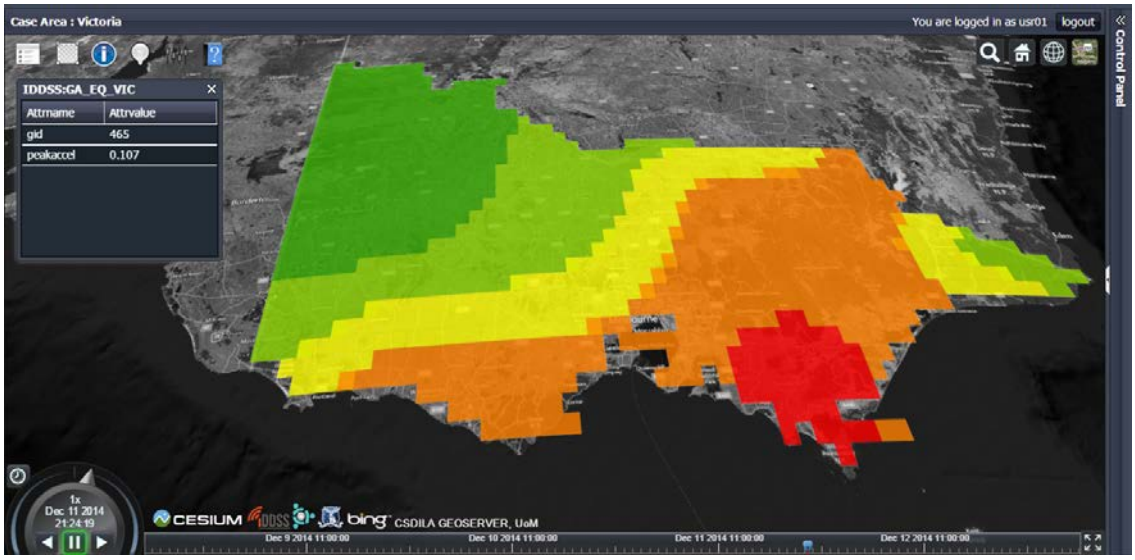


Figure 5: Earthquake hazard map

The Way Forward

Following the development of this multi-hazard map, the focus of the research team moved towards developing exposure and vulnerability maps for Victoria.

DEVELOPMENT OF A METHOD TO ESTIMATE THE EFFECT OF NATURAL DISASTERS ON SECTORAL ECONOMIC GROWTH OF AUSTRALIA

Estimating potential damage and losses as a result of natural disasters is a challenging task due to the multi-disciplinary nature of the events. Since the estimating of potential damage broadly initiates with the identification of the

source as well as determination of the probability of the occurrence of disasters, hazard modellers generally lead the whole process to estimate the potential destruction of infrastructures against a set of scenarios.

When it comes into loss estimation in natural disasters, the economists step in mainly using empirical econometric approach. However, to the best of our knowledge, no acceptable method has been devised to marry these two disciplines to estimate potential damage and losses coherently. In this component of the research a methodology to connect the multi-hazard disaster damage assessment approach with an empirical econometric strategy of estimating disaster losses in one spatial platform was proposed.

STUDY ON EXPOSURE ANALYSIS

A study and report on exposure analysis was conducted to provide a better understanding of the process required to achieve a multi-hazard risk assessment. The report introduces the basic components of risk assessment and then details the process of hazard assessment which allows the assessment of exposure and vulnerability. The exposure analysis is then discussed.

Initially the concept of risk assessment and mapping is outlined, followed by the approach and data requirements of a hazard assessment. Next the process undertaken for the exposure and vulnerability assessment is detailed including the sectoral exposure data collection and the vulnerability analysis. The final stages of risk assessment to lead to the multi-hazard risk assessment is not discussed within this report as it will be detailed extensively in subsequent reports.

ASSESSMENT OF DAMAGE AND CONSEQUENCE DATA FROM PAST HAZARD EVENTS IN VICTORIA

As a component of the research, an assessment was carried out on the damage and consequence data from past hazard events in Victoria. The assessment provides and overview of the natural hazard data used within the project and provides some statistics on the natural hazard events.

The original dataset contained information on all disaster events for Australia. There was data listed for a range of disaster events for all states and territories in Australia.
The original disaster events included were:

- Bushfire
- Chemical
- Complex emergencies
- Criminal act
- Cyclone
- Earthquake
- Environmental
- Epidemic
- Flood
- Hail

- Industrial
- Landslide
- Severe storm
- Shipwreck
- Tornado
- Transport
- Tsunami
- Urban fire

As the scope of this project relates only to natural hazard events, the disaster events that were not geophysical, meteorological, hydrological, climatological or biological events were removed. The data was classified using the EM-DAT International Disaster Database from the Centre for Research on the Epidemiology of Disasters (CRED). After this filtering eight primary disaster event types remained. Figure 6 shows the disaster classifications with the subgroups, disaster main types and the disaster sub-types.

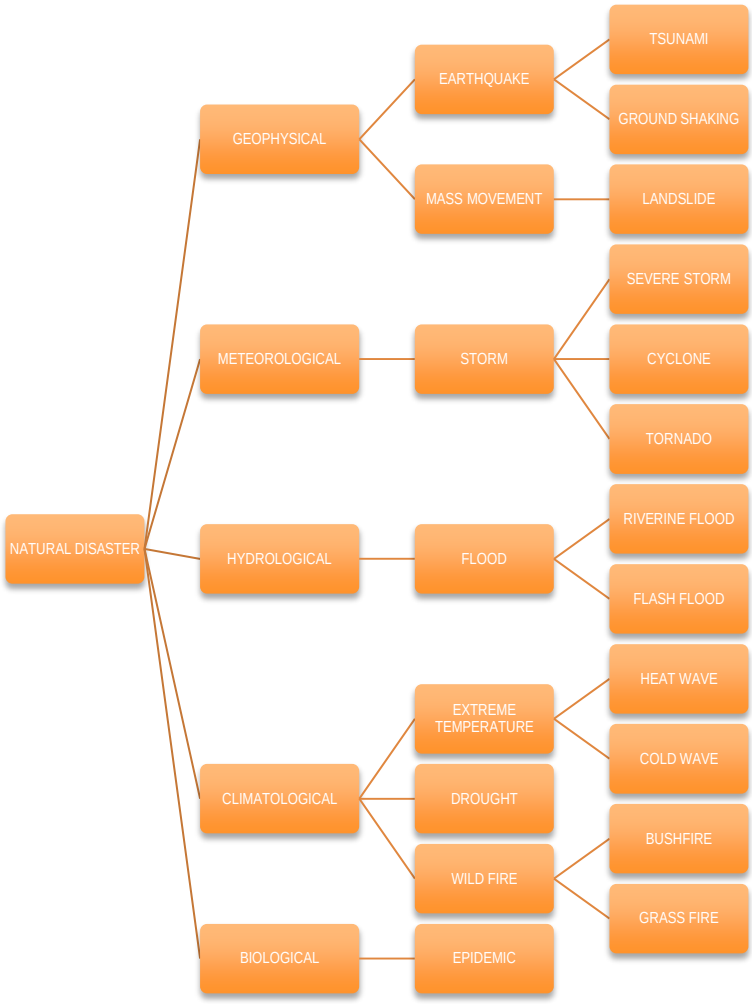


Figure 6: the disaster classifications

Following the classification a number of the original disasters were eliminated from the dataset, and some were reclassified into new disaster types. The disaster types of chemical, complex emergencies, criminal act, industrial, shipwreck,

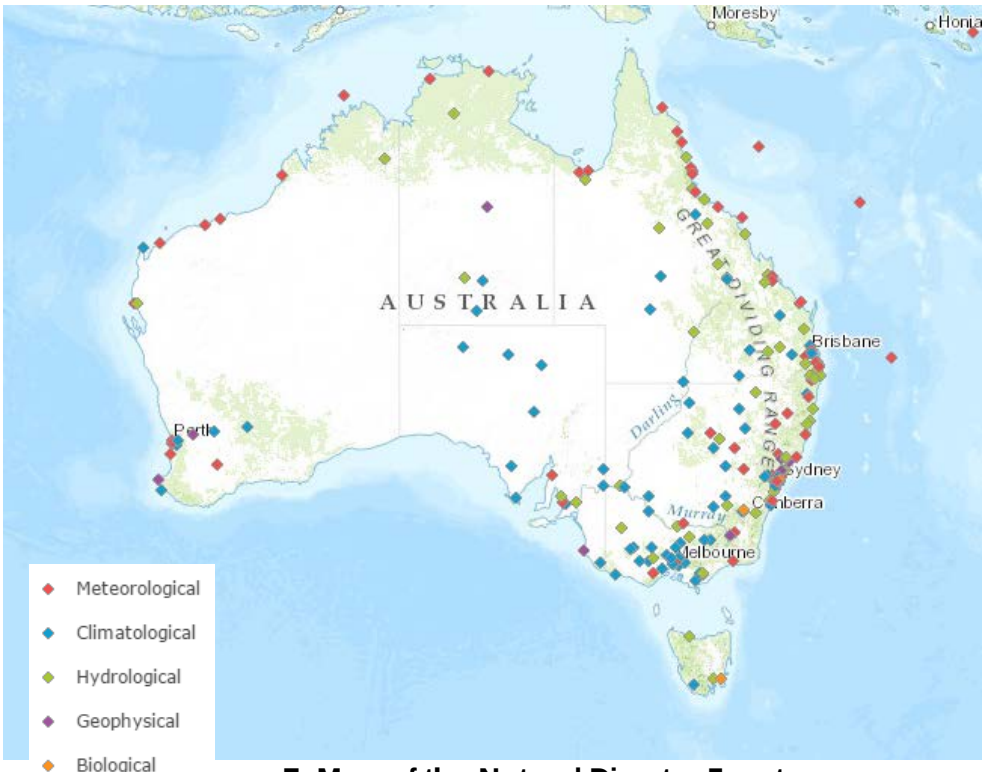
transport and urban fire were eliminated, while environmental was reclassified into the two disaster types of drought and extreme temperature, and hail was combined with severe storm.

After the removal of events that were not considered a natural disaster, the data was classified arranged into the subgroups of: disaster subgroup, disaster main type and disaster sub-types, as reflected in Figure 7. The results are shown below in Table 1.

Table 1: Count of disasters arranged by subgroup (all of Australia)

Disaster Subgroup	Count
Geophysical	14 in Total 10 Earthquake (9 Ground shaking; 1 Tsunami) 4 Mass Movement (4 Landslide)
Meteorological	109 in Total 109 Storm (38 Cyclone; 68 Severe Storm; 3 Tornado)
Hydrological	77 in Total 77 Flood (7 Flash Flood; 70 Riverine Flood)
Climatological	89 in Total 12 Drought 20 Extreme Temperature (19 Heat Wave; 1 Cold Wave) 57 Wild Fire (56 Bushfire; 1 Grass Fire)
Biological	11 in Total 11 (Epidemic)
Total	300

The disasters have been mapped below in terms of the disaster subgroup in Figure 7.



..gure 7: Map of the Natural Disaster Events

Following this classification, the state of Victoria then became the focus for further analysis.

The data was analyzed in a number of ways using the data relevant to the state of Victoria and a number of statistics were extracted. A summary of the statistics is shown below in Figure 8.

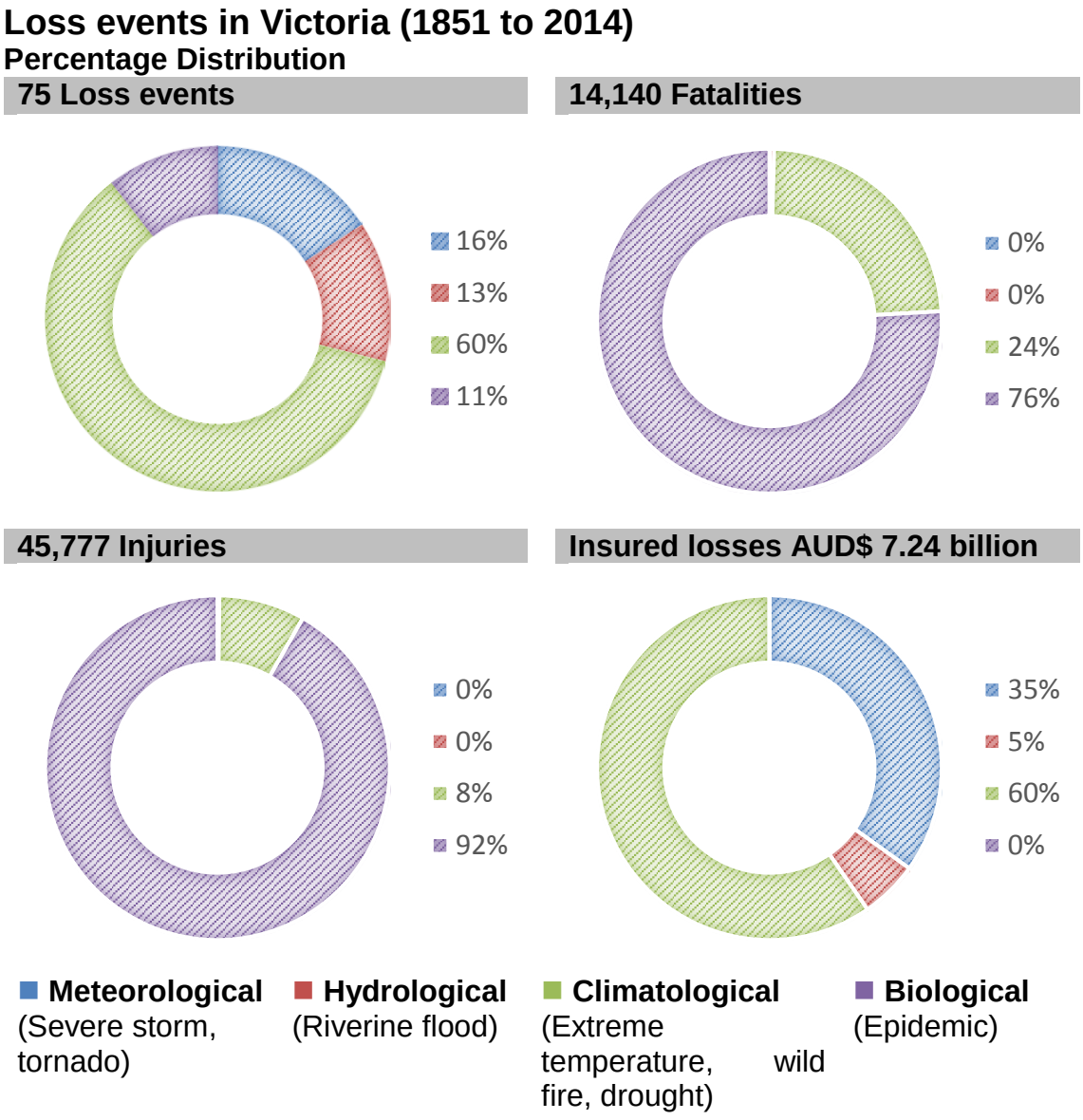


Figure 8: Loss events in Victoria (1851 to 2014)

Following the analysis of this data, this data which has been input into the PHiLEP system will be used to further develop the multi-hazard map for Victoria, as well as inputs for the exposure analysis, vulnerability map for Victoria and Australia and the multi-hazard risk map. This data will act as a foundation element to support the damage assessment and economic loss modelling components of the project.

ENGAGEMENT ACTIVITIES

To date, three end user workshops have been conducted – the first in July 2014, the second in December 2014 and the latest most recently in April 2015. At these workshops the team gave presentations and demonstrations on the project aims and objectives, the research method, reported on the results and progress, and demonstrated the outcomes through the PHiLEP system. In addition to these end user meetings, a visit to Canberra to present to AGD and GA end users has also taken place. Following the meeting in Canberra the research team has been in steady contact with AGD regarding the project and as a result the team is planning a second visit in the upcoming months.

In addition to the meetings, the research team engages regularly with the end users through email updates. So far, 11 progress update emails have been sent, which are used as opportunities to update the end users on our progress and keep them informed of our work, and offer an opportunity for the end users to give feedback.

PUBLICATIONS LIST

The research team has been very successful in communicating the outcomes of their work to date with a number of publications being produced. These publications include:

- A refereed paper accepted for the Australian Conference of Economics 2015
  - on the nexus between natural disasters and economic development in Australia
- A paper accepted for oral presentation at AFAC 2015
  - paper titled: bringing hazard and economic modellers together: a spatial platform for damage and losses visualisation
- A report on the multi-hazard map for Victoria
  - gives a detailed account of how the multi-hazard map was developed and showcases the PHiLEP system which supports the visualisation of the map.
- A report on exposure analysis component
  - introduces the basic components of risk assessment and then details process for conducting exposure analysis
- A report on the damage and consequence data from past hazard events in Victoria
  - introduces the basic components of risk assessment and then details process for conducting exposure analysis
- A paper accepted and delivered for oral presentation at AFAC 2014
  - paper titled: a pre-disaster multi-hazard damage and economic loss estimation model for Australia

CURRENT TEAM MEMBERS

The pre-disaster multi-hazard damage and economic loss estimation model team consists of many stakeholders from a range of organizations. These stakeholders are categorized into the three groups of researchers, students and end users.

RESEARCHERS

The researchers in this project hail from three different organizations – the University of Melbourne, Deakin University, and Asian Disaster Preparedness Centre (ADPC).

From the University of Melbourne

- Prof. Abbas Rajabifard
- Assoc. Prof. Nelson Lam
- Dr. Mohsen Kalantari
- Dr. Benny Chen
- Dr. Katie Potts

From Deakin University

- Assoc. Prof. Mehmet Ulubasoglu
- Dr. Prasad Bhattacharya
- Dr. Habibur Rahman

From the Asian Disaster Preparedness Center

- Dr. Peeranan Towashiraporn
- Ms. Anggraini Dewi

Together the members of the team meet regularly to collaborate and work together on components of the research. Meetings are held in person and online to accommodate the different locations of our researchers.

STUDENTS

Currently there is one PhD candidate aligned with this project – Roozbeh Hasanzadeh Nafari, from the University of Melbourne. Roozbeh's work is focused on flood damage assessment in urban areas.

END USERS

This project currently has a total of 8 end users from across industry. Two of these end users have recently joined the project following the research advisory forum held in Sydney in April – Joe Buffone from Emergency Management Victoria, and David Nichols from Country Fire Authority Victoria. The addition of these two new end users strengthens our Victorian end user base which will assist with the development and refinement of the Victorian case study and will help to advance quality end user based outcomes.

Name	Organisation
Ed Pikusa	South Australia Fire and Emergency Services Commission
Samantha Ward	Attorney-Generals Department
Martine Woolf	Geoscience Australia
Stuart Midgley	New South Wales Rural Fire Service
David Launder	South Australian Metropolitan Fire Service
Jill Edwards	Australian Fire and Emergency Services Authorities Council
Joe Buffone	Emergency Management Victoria
David Nichols	Country Fire Authority Victoria

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